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series, it has been the first object to secure as many measures of this kind as possible. During the past year the only satellites connected directly with the planet were the remote ones, *Titan* and *Hyperion*. W. J. HUSSEY.

RESIDUALS FOR OBSERVATIONS OF THE SATELLITES OF *URANUS* AND *NEPTUNE*.

I have compared my observations of the satellites of *Uranus*, made in 1897 and 1898, with places computed by means of Professor NEWCOMB'S tables of their motions, given in Appendix I of the Washington Observations for 1873. The average values of the residuals, in the sense O–C, are as follows :—

Ariel	+ 1°.5	— 0″.19
Umbriel . .	+ 2 .0	+ 0 .12
Titania . . .	+ 1 .3	— 0 .05
Oberon . . .	+ 0 .6	— 0 .17

These residuals, like those recently published by Professor AITKEN, show that the satellites are slightly in advance of their predicted places. The differences, however, between the observed and computed position-angles are very small, and would vanish if the adopted mean motions were very slightly increased.

I have also compared my observations of the satellite of *Neptune* with places computed by means of Dr. HERMANN STRUVE'S elements. The average values are as follows :—

Satellite of *Neptune* . . + 0°.2 + 0″.33

These elements represent the observation on angle with great exactness, all the residuals being of the same order of magnitude as the probable errors of observation. W. J. HUSSEY.

THE PRESSURE OF HEAT AND LIGHT RADIATION.

At the meeting of the American Association for the Advancement of Science, held in Denver in August, 1901, a paper* by Professor E. F. NICHOLS and Mr. G. F. HULL, of Dartmouth College, was read, giving an account of their experiments in determining the pressure of heat and light. A paper on the same subject was read by Professor NICHOLS at the meeting of the Astronomical and Astrophysical Society of America at Washington, in December, 1901.

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* Published in the *Physical Review*, Vol. XIII, No. 5, November, 1901.

The experimental proof that such a pressure is exerted by light is of great importance to astronomy. Such a property of light offers a reasonable explanation of several very perplexing phenomena, and will doubtless be found to assist materially in the solution of others.

Pressure of this character was first suggested by MAXWELL in dealing theoretically with the stresses in an electromagnetic field. BARTOLI later announced that a similar pressure was essential to one of the fundamental laws of thermodynamics. He failed, however, to detect such an effect experimentally, from the difficulty of isolating the phenomenon. Other investigators have discussed the problem theoretically, and especially the applications of such a pressure to the solution of various observed phenomena, in which many interesting results have been reached. The experimental solution had failed, however, owing to the action of gases surrounding the body experimented upon which it was found impossible to eliminate. The molecules of such gas exerted pressure which completely masked the force which it was sought to measure.

Following are the considerations acted upon by NICHOLS and HULL in their successful attempt to isolate this force :—

"1. The surfaces which receive the radiation, the pressure of which is to be measured, should be as perfect reflectors as possible. This will reduce the gas-action by making the rise of temperature due to absorption small, while the radiation-pressure will be increased ; the theory requiring that a beam, totally reflected, exert twice the pressure of an equal beam completely absorbed.

"2. By studying the action of a beam of constant intensity upon the same surface surrounded by air at different pressures, certain pressures may be found where the gas-action is smaller than at others.

"3. The apparatus—some sort of torsion-balance—should carry two surfaces systematically placed with reference to the rotation-axis, and the surfaces on the two arms should be as nearly equal as possible in every respect save one—the forces due to radiation and gas-action should have the same sign on one side and opposite signs on the other. In this way a mean of the resultant forces on the two sides should be, in part at least, free from gas-action.

"4. Radiation-pressure, from its nature, must reach its maximum value instantly, while observation has shown that the gas-action begins at zero and increases with length of exposure, rising rapidly at first, then more slowly to its maximum effect, which, in most of the cases observed, was not reached until the exposure had lasted from 2½ to 3 minutes. For large gas-pressures, an even longer exposure was necessary to reach stationary conditions. The gas-action may be thus still further reduced by a ballistic or semi-ballistic method of measurement."

The apparatus for the observation of these pressures consisted of a delicate and especially arranged torsion-balance carrying two small glass vanes, one on either side of the rotation axis. Each of the vanes had one of its sides silvered and highly polished. These vanes were so hung that the glass face of one and the silvered face of the other were turned to the light. A beam of light from an arc-lamp was allowed to fall in turn upon each vane, and the deflection of the balance read by a telescope in which was observed the image of a scale reflected in a small mirror attached to the balance. At the same time that the deflection of the vanes was observed the intensity of the beam of light was observed by means of a thermopile and galvanometer. The balance was placed in a bell-jar which was connected with an air-pump and a large part of the air exhausted. The first observations consisted in allowing the beam of light to fall upon each vane for a sufficient time to allow the conditions of gas-pressure and radiation-pressure to become stationary, as indicated by the balance coming to rest. This was done for each vane in succession, and observations made at eight gas-pressures between 0.06^{mm} and 96^{mm} of mercury. The results, however, showed such complicated gas-actions at certain pressures that no certain conclusions could be drawn as to the existence of a constant force such as that sought. A comparison of these observations with the more accurate ones obtained later by means of short exposures, showed that in the first series the gas-action varied from one tenth to 6 or 7 times the actual pressure of light.

In the method of short exposures the light was allowed to fall on the vane for 6 seconds, which was one fourth of the period of vibration of the balance and the resulting deflection computed from the known laws of such a system. In this way very definite results were secured, as shown in the following table :—

p	d
96.3	19.7
67.7	21.0
37.9	21.6
36.5	22.1
33.4	21.1
1.2	20.9
0.13	26.8
0.06	23.2
Mean,	22.5

The column p gives the gas-pressure in the bell-jar in millimeters of mercury, and column d the permanent deflection in millimeters due to radiation-pressure. From the known constant of the torsion-balance this deflection gives 1.05×10^{-4} dynes as the radiation pressure.

By means of a bolometer constructed for the purpose, the energy of the radiation causing these deflections was measured, and it was found to correspond to a pressure of 1.34×10^{-4} dynes. The observations, therefore, show 78 per cent. of the total pressure of the beam indicated by the bolometer measurements. Some of the sources of error in the bolometer results which would tend to bring the observations into better agreement are indicated by the investigators.

According to a letter from Professor NICHOLS, later observations with improved apparatus have reduced the difference between the pressure of the radiation as measured directly and that indicated from theory, through measurements of the beam of light with the bolometer, to 5 per cent. This difference is extremely small, considering the difficult nature of the observations.

Ten years ago LEBEDEW explained the anomalous appearances exhibited by the tails of comets by assuming such a pressure of light to act in opposition to the Sun's attractive force. Such a theory accounts for the different types of cometary tails by supposing that the individual particles composing them are of different sizes.

As the velocity due to gravity depends upon the *mass* of the particle, while the velocity due to radiation-pressure depends upon the *surface*, the resultant will be different for particles of different sizes. Comparatively large particles will obey the force of gravity, while in the case of the smaller ones the radiation-pressure will be most effective and will cause them to move in opposition to gravity. The smallest rapidly moving particles would thus compose the long, straight tails of comets, while the short, curved tails would be composed of larger particles. Particles still larger would be acted upon sufficiently by gravity to cause them to move towards the Sun.

This explanation of cometary phenomena has recently been revived by ARRHENIUS, and the theory of radiation-pressures extended to cover a number of other phenomena — e. g., the Zodiacal Light, Gegenschein, Aurora Borealis, etc.

This property of radiation must be nearly as wide-spread as gravity itself, and will have to be considered in all theories relating to finely divided matter at least.

It is perhaps not too much to expect that ere long we shall know much more of this new property of light and heat, especially its relations to different wave-lengths.

C. D. PERRINE.

MT. HAMILTON, CALIFORNIA, March 19, 1902.

ORIGIN OF A DISTURBED REGION OBSERVED IN THE CORONA OF 1901, MAY 17–18TH.

One of the most conspicuous features of the recent eclipse was an area of disturbance in the Corona off the east limb, to which I called attention in my first reports.*

The disturbance had the form of an inverted cone, with its apex on or very near the Sun's limb. It had the appearance of being composed of cloudlike masses of matter, arranged in such a manner as we should expect if it were the result of an eruption on the Sun's surface. In fact, the appearance alone very strongly suggests such an origin. Close to the apex of this region is a long, slender prominence, almost tangential to the limb, which seems to have had its origin at the same point as the coronal disturbance.

No spots or unusual faculæ had been observed just previous to the eclipse, nor were any observations or photographs available until recently with which to investigate the question of origin. Through the kindness of the Astronomer Royal, Royal Observatory, Greenwich, the Lick Observatory has been supplied with copies on glass of the negatives of the Sun taken at Dehra Dûn, India, on May 17, 18, 19, 20, 21, 22, 26, and 28, 1901. These photographs are on a scale of 7½ inches to the solar diameter and furnish the requisite data.

The photographs of May 17th and 18th show no spots or other evidences of unusual activity on any part of the Sun's disc. On the photograph of May 19th, however, is a spot of medium size which has just appeared around the east limb. Owing to foreshortening, the spot, on this date, is little more than a line ½′ in length, surrounded by faculæ. On the 20th it is ¾′ in length (north and south), and is followed at a distance of ½′ by several small spots, forming a close group.

The principal spot is compact, with well-defined umbra and

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* Lick Observatory *Bulletin*, No. 9. *Publications A. S. P.*, Vol. XIII, p. 196.